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Relationship of Employee Attitudes and Supervisor-Controller Ratio to En Route Operational Error Rates

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16. Abstract

An operational error (OE) results when an air traffic control specialist (ATCS) fails to maintain appropriate separation between aircraft, obstacles, etc. Recent research on OEs has focused on situational and individual characteristics (Center for Naval Analyses Corporation, 1995; Della Rocco, 1999; Rodgers, Mogford, Mogford, 1998). In this study, the relationship of organizational factors to en route OE rates was investigated, based on an adaptation of the Human Factors Analysis and Classification System (HFACS; Shappell & Wiegmann, 2000) to air traffic control as HFACS-ATC (Scarborough & Pounds, 2001). OE rates (errors per 100,000 operations) for 1997 and 2000 were obtained from the National Airspace Incident Monitoring System (NAIMS) for 21 air route traffic control centers (ARTCC). Organizational factors were represented by facility mean scores on scales constructed from 1997 and 2000 FAA Employee Attitude Survey (EAS) data. Factors included employee perceptions of equipment/facilities, performance management, overall job satisfaction, and perceptions of other human resources management practices. The supervisor-controller ratio (SCR) was calculated for each ARTCC by year from agency personnel data. SCR and organizational factors facility mean scores were regressed on OE rate (N=42). Two organizational factors and SCR accounted for 50% (adjusted R^2 = .505, p < .001) of the variance in OE rates across ARTCCs for the two years. The standardized regression coefficients were -.290 for perceptions of equipment/facilities (t=-2.07, p < .05), -.302 for perceptions of performance management (t=-2.28, p < .05), and -.395 for SCR (t=-3.360, p < .01). As expected from prior research, SCR was a significant predictor of en route OE rates. In addition, the results indicated that perceptions of how performance was managed and of facilities and equipment were also predictors of OE rates. Overall, the results support the inclusion of organizational factors as well as individual and situational characteristics in the investigation of ATCS operational errors.

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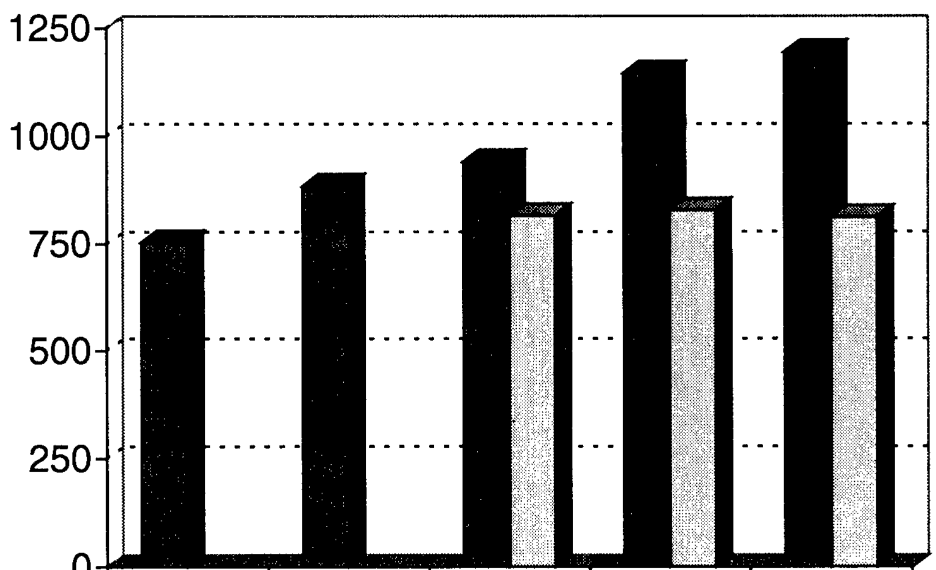
Relationship of Employee Attitudes and Supervisor-Controller Ratio to En Route Operational Error Rates

Air traffic controllers ensure the safe, orderly, and expeditious flow of air traffic through the National Airspace System (NAS). To ensure the safety of flight, controllers maintain adequate separation between aircraft and obstacles to flight. They issue speed, altitude, and heading commands to pilots to provide and maintain required separation. An operational error (OE) results when an Air Traffic Control Specialist (ATCS, "air traffic controller," or "controller") fails to maintain appropriate separation between aircraft, terrain, and other obstacles to safe flight. The number of OEs per 100,000 facility activities ("OE rate") has long been an index of NAS safety. Reduction in the OE rate is a safety goal for the FAA "line-of-business" responsible for the delivery and management of air traffic services. For example, the *Air Traffic Services Performance Plan FY2001-2003* (Air Traffic Services, 2000) calls for the reduction of OEs by 2.5% per year in FY2002 and FY2003.

However, the OE rate has increased in recent years. For example, the number of OEs increased from 754 in fiscal year (FY) 1997 to 1,194 in FY2001.The goal for FY2001 was 812 errors (Figure 1). The rate also increased, from .51 to .68 per 100,000 facility operations (Department of Transportation Office of the Inspector General, 2000, 2002). Explanations for the increase include better reporting and increased traffic. Possible situational and individual causal factors have been investigated in several studies (see, for examples, Broach, 1999; Della Rocco, Cruz, & Clemens, 1999; Endlsey & Rodgers, 1997; Rodgers & Nye, 1993; Rodgers, Mogford, & Mogford, 1998; Schroeder & Nye, 1993). The Center for Naval Analyses Corporation (CNAC, 1995) examined the relationship of individual characteristics, staffing ratios, and facility characteristics to en route OEs for the period 1990 through 1995. There appeared to be little correlation between the supervisor-controller staffing ratio and



	1997	1998	1999	2000	2001
OE	754	885	941	1145	1194
Goal			816	829	812

Figure 1: Actual operational errors (OE) and goal by fiscal year (Adapted From Department of Transportation Office of the Inspector General, 2002)

the OE rate (p. 94). CNAC concluded that the number of OEs were primarily a function of the complexity of the sectors being supervised rather than individual characteristics of the supervisor (p. 97).

This study replicated and extended the CNAC study by focusing on the influence of organizational characteristics on OE rate at the 21 continental air route traffic control centers (ARTCCs, or centers). Organizational characteristics have been hypothesized to influence the occurrence of human errors (Reason, 1990; Shappell & Wiegmann, 2000). Organizational characteristics in the Human Factors Classification and Analysis System–Air Traffic Control (HFACS-ATC; Scarborough & Pounds, 2001) include (a) *organizational climate*, (b) *organizational structure*, (c) *policies and procedures*, and (c) *resource management*.

Organizational climate in HFACS-ATC refers to the working atmosphere within the organization. An organizational climate characterized by confusion and conflict may have a detrimental effect on safety (Shappell & Wiegmann, p. 13). Job satisfaction, for example, might serve as an overall indicator of the organizational climate. Schneider (2001) investigated the relationship of job satisfaction to operational errors in the en route environment. Facility mean scores were computed for selected items from the FAA's 1997 Employee Attitude Survey (EAS). Schneider then correlated those scores with the number of OEs for each en route facility (N = 21). No significant correlations between operational errors and various measures of job satisfaction were found. *Organizational structure* refers to attributes such as the ratio of supervisors to controllers and the hierarchical organization of the facility. The 1995 CNAC study reported no significant correlation between OE rates and the ratio of supervisors to controllers. However, Fisher (2001) qualitatively linked reductions in the number of operational supervisors, an organizational structure characteristic, to increases in operational errors. Other facets of organizational structure might include the degree of oversight exercised over employees, and the accountability of management employees for performance. *Policies and procedures* in the HFACS-ATC refer to the broad class of corporate decisions and rules that structure everyday working life. Kinney (1977) qualitatively described how organizational policies influenced the occurrence of operational errors. However, no recent research has investigated the influence of organizational policies and procedures. Finally, *resource management* in HFACS-ATC encompasses the allocation of organizational assets such as personnel, money, and facilities or equipment. One aspect of resource management might be employee perceptions of the quality of equipment, the facility overall, and maintenance services. The purpose of the present study was to explore possible relationships between several of the organizational facets proposed by HFACS-ATC to OE rates in today's air traffic control system.

METHOD

Data sources

OE rates (errors per 100,000 operations) were obtained from the National Airspace Incident Monitoring System (NAIMS) for calendar years 1997 and 2000 for 21 U.S. ARTCCs. The combined en route/approach control facilities in Guam, Hawaii, and Puerto Rico were excluded from the analysis as they are operationally different from the 21 continental air route traffic control centers. Response data for selected items from the EAS for the years 1997 and 2000 were used to construct the organizational factors used in this study. Staffing data for 1997 and 2000 were extracted from the FAA's Consolidated Personnel Management Information System (CPMIS), the agency's official system of personnel records.

Organizational factors

Items from the EAS for 1997 and 2000 were selected to represent the organizational factors hypothesized to influence operational errors in the HFACS-ATC model. The EAS is a broad instrument used to assess FAA employee perceptions of the workplace (Thompson, et al., 2000). Sufficient organizational demographic data were collected from each respondent to allow segmentation of the data by workforce and facility. The overall response rate from the 21 centers were 41% in 1997 and 33% in 2000. Centers have, on average, about 300 controllers, with the exception of Anchorage which has just over 200 controllers.

The mapping of 1997 and 2000 EAS items and scales to the HFACS-ATC organizational factors is shown in Table 1. Only items that had remained unchanged between the two EAS administrations were considered to ensure comparability across years. A measure of the internal consistency, known generally as Cronbach's alpha (α; Cronbach, 1951), or the degree to which the items were related to one another, was calculated for each set of items selected to represent a HFACS-ATC factor. Cronbach's α can be computed if there are at least two items in the scale. Higher values for Cronbach's α for a HFACS-ATC factor indicated greater consistency in responses to the items, while lower values indicated less consistency.

Table 1:
Mapping of EAS items to HFACS-ATC organizational factors

HFACS-ATC Factor *Definition* EAS (Year) 1997 Items	2000 Items	**HFACS-ATC DOMAIN NAME** *Definition*
		ORGANIZATIONAL CLIMATE *Prevailing atmosphere within the organization. Morale/job satisfaction*
Workforce Attitudes (HFACSAT1) *Prevailing attitudes of the workforce, e.g., Job satisfaction, trust, contextual performance.*		
Q5	Q5	Overall, how satisfied are you with: your job – the kind of work you do?
Q9	Q8	Overall, how satisfied are you with: your job overall?
Q97	Q23 (R)	Some employees may be hesitant to speak up for fear of retaliation.
Q98	Q24 (R)	It is generally safer to say that you agree with management even when you don't really agree.
Q99	Q25	We are encouraged to express our concerns openly.
Workforce Behavioral Factors (HFACSAT2): *Prevailing behavioral sets of the workforce, e.g., following the rules.*		
Q75	Q96	To what extent are there things about working in the organization (such as policies, practices, or conditions) that encourage you to work hard?
Q78	Q107	To what extent does the FAA inspire the very best in you?
Informal Socialization Processes (HFACSAT3): *The process used to teach new members of the organization the Attitudinal and Behavioral Workforce Factors, e.g., Communicating the rules of the organization. Includes such things as describing how to interact with managers and supervisors, the organization's "real" values and priorities.*		
Q29	Q34	To what extent has the FAA done a good job creating an environment where all employees have the opportunity to broaden their knowledge of the FAA (e.g., town hall meetings, attending briefings)?
Q47	Q57	My immediate supervisor is fair with subordinates.
Q48	Q58	My immediate supervisor keeps informed about the way subordinates think and feel about things.

(Table 1 continues)

(Table 1 continued)

Q51	Q61 (R)	My immediate supervisor tends to play favorites.
Q96	Q84	I feel free to discuss with my immediate supervisor the problems and difficulties I have in my job without jeopardizing my position or having it "held against" me later.
Q69	Q100	To what extent do you receive sufficient information from the FAA to understand how major innovations and changes might affect you?
		ORGANIZATIONAL STRUCTURE *e.g., Chain-of-command, delegation of authority and responsibility, communication channels, and accountability for actions. Organizations with maladaptive structures will be more prone to accidents and incidents.*
Structural Oversight (HFACSAT4): *Control vs. commitment, number of levels from top to bottom; span of control, e.g., number of people supervised, availability of communication channels, support for programs which are initiated.*		
Q25	Q22	In my organization, managers show commitment to customer support through their actions.
Q87	Q85	Managers and supervisors in my organization are held accountable for achieving important agency goals.
Q88	Q86	Nonsupervisory employees in my organization are held accountable for achieving important agency goals.
Decision Making Structure (HFACSAT5): *The hierarchical and decision flow process of information during a decision making episode. Level of accountability; Level of responsibility; Level of empowerment, e.g., level of ATC responsibility for incidents.*		
Q17 (R)	Q17 (R)	I am required to get approval for decisions that I think I should be able to make myself.
Q18	Q18	Decisions in my organization are made at those levels where the most adequate and accurate information is available.
Q19	Q19	I am able to contribute to decision-making that affects my job.
Q20	Q20	I have the authority to make decisions required by my day-to-day work problems.

(Table 1 continues)

(Table 1 continued)

RESOURCE MANAGEMENT *Management, allocation, and maintenance of organizational resources.*		
Equipment & Facilities (HFACSAT8): *Refers to issues related to facility and equipment design, including the inadequate design of equipment and work spaces, and failures to correct known design flaws. Also failures to correct known facility shortcomings.*		
Q4	Q4	Overall, how satisfied are you with your physical working conditions?

Notes: (R) indicates item that is reversed for scoring purposes.

Table 2
Descriptive statistics and correlation matrix for operational error rate, supervisor-controller ratio, and HFACS-ATC organizational factors (N=42)[a]

	Descriptive Statistics				Correlations							
	Mean	SD	Min	Max	OE_RATE	SCR	HFACSAT 1	HFACSAT 2	HFACSAT 3	HFACSAT 4	HFACSAT 6	HFACSAT 7
OE_RATE OEs per 100,000 Ops	1.21	0.65	0.07	3.46								
SCR Supervisor-Controller Ratio	0.14	0.02	0.11	0.22	-0.54**							
HFACSAT1 Attitudinal Factors	3.15	0.12	2.89	3.41	-0.22	0.01						
HFACSAT2 Behavioral Factors	2.04	0.19	1.64	2.42	-0.43**	0.04	0.60**					
HFACSAT3 Informal Socialization	2.95	0.14	2.56	3.22	-0.48**	0.17	0.68**	0.70**				
HFACSAT4 Structural Oversight	2.56	0.17	2.23	2.95	-0.40**	0.15	0.45**	0.71**	0.72**			
HFACSAT6 Human Resources	2.64	0.14	2.32	2.94	-0.45**	0.23	0.62**	0.50**	0.79**	0.59**		
HFACSAT7 Performance Management	2.35	0.16	1.94	2.66	-0.52**	0.14	0.70**	0.74**	0.85**	0.81**	0.75*	
HFACSAT8 Equipment & Facilities	2.70	0.55	1.28	3.78	-0.59**	0.35*	0.34*	0.68**	0.53**	0.57**	0.33*	0.56*

Notes: [a]Descriptive statistics are aggregated facility mean scores

* $p \leq .05$, ** $p \leq .01$

Although there is no absolute cut-off, scales with alphas of less than about .5 to .6 are not commonly used in research, as the scores on such scales are viewed as unreliable.

There were multiple items from both iterations of the EAS related to the HFACS-ATC *organizational climate* factor. Two EAS items specifically assessed job satisfaction, and three directly assessed employee trust. A scale to represent the workforce attitudes (HFACSAT1; Cronbach's α = .73) was constructed from these five items. The underlying hypothesis was that facilities with higher satisfaction and trust were more likely to have lower error rates. Another aspect of organizational climate is the extent to which employees were willing to work hard. Two items from the EAS addressed this facet of the facility organizational climate (HFACSAT2; Cronbach's α = .67), with the underlying hypothesis that facilities with higher levels of willingness to work hard would have lower OE rates. How employees are socialized into the organization plays a role in determining the organizational climate. Six items were identified from the EAS related to the informal socialization process (HFACSAT3; Cronbach's α = .81). The underlying hypothesis for these items was that facilities with more positive perceptions of informal socialization processes would have lower error rates.

The *organizational structure* factor of the HFACS-ATC model was represented by two scales derived by combining EAS items. First, three EAS items referring to managerial accountability and commitment to customer support were combined to represent general supervision (HFACSAT4; Cronbach's α = .58). We expected that facilities with more positive perceptions of general supervision would have lower OE rates. Second, four EAS items specifically focused on empowerment were used to represent decision-making structure (HFACSAT5), with the expectation that facilities with higher levels of perceived empowerment would have lower error rates. However, this "decision-making structure" scale was dropped from the analysis due to poor reliability (Cronbach's α = .25).

The *policies and procedures* facet of the organization was reflected in two scales constructed from the EAS. Six EAS items addressed human resources management policies such as training and promotion opportunity (HFACSAT6; Cronbach's α = .68). As with the other HFACS-ATC scales, we hypothesized that facilities with more positive perceptions of human resources management policies would have lower error rates. Five EAS items focused on *performance management* (HFACSAT7; Cronbach's α = .67). We hypothesized that facilities with more positive perceptions of performance management would also likely experience lower error rates. Finally, *resource management* was reflected by a single scale addressing the quality of equipment and facilities. A single EAS item was used to represent employee perceptions of the quality of equipment and facilities (HFACSAT8), with the expectation that more positive perceptions would be reflected in lower facility error rates. Scale scores were calculated for each respondent. The six reliable, multi-item scales and HFACSAT7 (a single item scale) were then aggregated by year and facility. The resulting data file included facility identifier, number of respondents, and the facility mean scores on the seven HFACS-ATC scales (HFACSAT1 to HFACSAT4, HFACSAT6 to HFACSAT8) by year and facility.

Employment data extracted from the FAA's CPMIS were used to estimate the supervisor-to-controller ratio (SCR) in 1997 and 2000 for each center. The SCR was computed as the ratio of the number of Operations Supervisors to the total number of Certified Professional Controllers and controllers in training at each center at the end of calendar years 1997 and 2000. The SCR represented an objective measure of an aspect of the organizational structure.

Error data and analyses

Operational error data were extracted from the National Airspace Incident Monitoring System (NAIMS). SCR and OE (errors per 100,000 operations) were matched by year and center with the aggregated HFACS-ATC scale data file created for this analysis. The OE rate was regressed on the seven mean HFACS-ATC scale scores and the SCR. SPSS® for Windows (Version 10.0.7; SPSS, Inc., 1999) was used for all file manipulations and statistical analyses.

RESULTS

Descriptive statistics across centers and the correlation matrix are displayed in Table 2. The correlations between operational error rate (OE_RATE) and the hypothesized predictors were all negative and significant. The correlation between SCR and OE_RATE was -.54 ($p \leq .001$; Figure 2). In other words, facilities with about 1 supervisor for every 6-7 controllers (SCR = .14 to .17) had lower error rates than facilities with 1 supervisor for every 8-10 controllers (SCR = .10 to .12).The moderate to moderately large correlations between the HFACS-ATC factors suggested that collinearity might be problem for the analysis. Collinearity refers to the degree to which the predictors are related to one another. When the predictors are highly related to one another, the information each provides

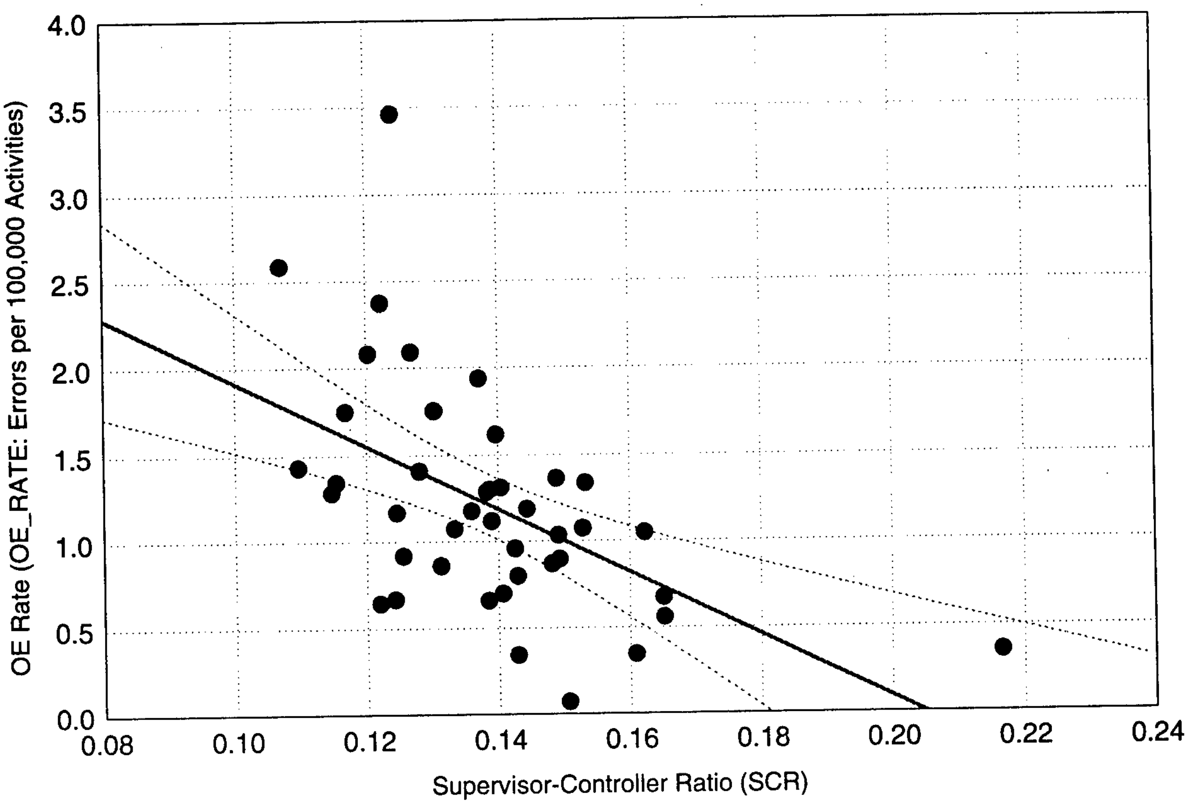


Figure 2: Correlation ($r = -.54$, $p \leq .001$) between Supervisor-Controller Ration (SCR) & Operational Error Rate (OE_RATE)

may be duplicated by the other predictors. As a result, a regression analysis based on highly correlated predictors will be unstable, as one predictor could easily be substituted for another. Therefore, in view of the apparent collinearity among the predictors, regression diagnostics were examined during the course of the analysis.

The results of the stepwise regression of the seven HFACS-ATC scale scores and SCR on the operational error rate are shown in Table 3. Stepwise regression is a technique for identifying the optimally weighted variables from a given set that best predict the criterion (OE_RATE in this instance). Regression diagnostics provided little evidence of problematic collinearity. Variance inflation factor (VIF) scores, a commonly used regression diagnostic, ranged from 1.143 to 1.622 for the three predictor scales that comprised the final model. VIF is equal to 1.0 when the predictors are independent and have no correlation with one another; a value of 10 or greater is often used as a benchmark indicating problematic collinearity among the predictors. VIF scores near 1 indicated that the optimally weighted set of variables that best predicted OE_RATE was stable and interpretable.

Overall, the supervisor-controller ratio (SCR), employee perceptions of how performance was managed in the facility (HFACSAT7), and employee perceptions of the quality of equipment and facilities (HFACSAT8) accounted for 51% (Adjusted R^2 = .505, $F(3,38) = 14.925$, $p \leq .001$) of the variance in 1997 and 2000 operational error rates across the 21 centers. The other factors did not meet the statistical criteria for inclusion in the final model.

The adjusted R^2 is a conservative estimate of the relationship between the predictors (SCR, HFACSAT7, HFACSAT8) and OE_RATE. The adjusted R^2 indicates how well OE_RATE can be predicted from the combination of weighted variables. An R^2 of 1.00 indicates that the criterion (OE_RATE) is perfectly predicted from SCR, HFACSAT7, and HFACSAT8. Conversely, an $R^2 = 0$ indicates that OE_RATE could not be predicted at all from SCR, HFACSAT7, and HFACSAT8. An R^2 of about .3 is very common in the social sciences, particularly in attitude-related research. An R^2 of .5 is much less common, and indicates that supervisor-controller ratio, employee perceptions of how performance is

Table 3
Results of stepwise regression of ARTCC operational error rate on supervisor-controller ratio and HFACS-ATC organizational factors

	Regression Coefficients								
	B	SE_B	β	*t*	*R*	ΔR^2	R^2	Adj-R^2	*F*
				Model 1					
Intercept	3.129	.417		7.495***					
HFACSAT8	-.709	.151	-.595	-4.681***	.595	.354	.354	.338	21.912***
				Model 2					
Intercept	4.479	.584		7.674***					
HFACSAT8	-.553	.147	-.464	-3.765**					
SCR	-12.782	4.190	-.376	-3.048**	.692	.124**	.478	.451	17.870***
				Model 3					
Intercept	6.880	1.191		5.780***					
HFACSAT8	-.345	.167	-.290	-2.071*					
SCR	-13.425	3.995	-.395	-3.360**					
HFACSAT7	-1.225	.538	-.302	-2.279*	.735	.063*	.541	.505	14.925***

$^*p \le .05$, $^{**}p \le .001$, $^{***}p \le .001$

managed and the facilities and equipment have some relationship to the operational error rate at each en route center.

DISCUSSION

The results of this descriptive study suggest that organizational factors might influence the operational error rate in en route air traffic control at the facility level. This conclusion provides support for including organizational factors in the analysis of operational errors as suggested by HFACS-ATC. The regression analysis also suggests that span-of-control, as represented by the supervisor-to-controller ratio, may be related to en route facility operational error rates.

On the one hand, the analysis indicated that both subjective and objective measures might be useful in explaining differences in error rates between centers. Similar results have been found in examining organizational and work unit attitudes towards safety and accidents in other settings. For example, Zohar (2000) demonstrated an empirical link between perceptions of organizational safety climate and objective injury data. Similarly, Thompson, Hilton, and Witt (1997) demonstrated how perceptions of organizational climate and management roles might affect safety-related outcomes. The measures drawn from the EAS reflect subjective perceptions of equipment and performance management. In contrast, the SCR represents an objective, structural characteristic of each center. Overall, the present analysis *suggests* that it would be fruitful for human factors investigations of operational errors in air traffic control to take into account subjective perceptions of the organizational climate, including perceptions of safety, as well as objective characteristics of the organizational structure.

On the other hand, the study is descriptive, and it is unlikely that future operational error rates at a particular facility can be predicted from past measures of employee attitudes or supervisor-controller ratios. Moreover, the results of this analysis are not consistent with those reported by CNAC (1995) with respect to supervisor-controller ratio. In that study, staffing ratio, based on mid-year figures, was regressed on the yearly average error rate (CNAC, 1995, p. 94). It is not clear from the description whether the averages were computed across facilities, across years, or both. Consequently, it is unclear as to how to interpret the results of the present study with respect to the CNAC study. Further research is clearly needed to explore and explain any differences as well as to replicate the findings of the present study.

Finally, it must be noted that this study did not examine relationships between attitudes and errors at the level of the individual controller. The unit of analysis for this study was the facility. The attitudinal predictors were composite, aggregated average scores at the facility level created from anonymous survey data. EAS data cannot be matched with OE data, as the EAS is anonymous, and the final OE reports do not identify the involved controller(s). The results of this study cannot be used in any way to predict the likelihood of an individual controller being involved in an operational error. However, they do underscore the need to collect data at multiple levels of analysis, including organizational characteristics as well as information on the individual controllers involved in errors. While the organizational data might or might not be relevant to any single OE, patterns across errors and over time might be found. Identification of such patterns, in turn, might guide interventions and risk mitigation strategies as the FAA actively seeks to reduce the incidence of en route operational errors.

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